TECHNICAL REPORT
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A HUMAN FACTORS EVALUATION OF COLD WEATHER FACE MASKS

by

Carolyn K. Bensel

Richard F. Q. Johnson

Thomas L. Nichols

April 1972

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UNITED STATES ARMY
NATICK LABORATORIES
Natick, Massachusetts 01760

U.S. ARMY MATERIEL COMMAND

Pioneering Research Laboratory

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13. ABSTRACT

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Foreword

The study reported here was conducted by the Human Factors Group, Behaviorial Sciences Division, PRL, at the request of the Clothing and Personal Life Support Equipment Laboratory. This work was carried on as part of Task 05 under Project Number 1J664713DL40, Mask, Cold Weather (LINCLOE), and Task 02 under Project Number 1T062106A121, Human Factors Analysis and Design Guidance in Support of Materiel Research and Development.

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Abstract

A human factors evaluation of three types of cold weather face masks (the Army standard and two experimental masks) was made in a series of investigations: a visual field investigation, a psychoacoustic investigation, a personal and equipment compatibility test, and an arctic chamber test. Results indicated that (a) all three masks were virtually equivalent with respect to the size of the field of vision and personal/equipment compatibility, (b) acceptability of the masks varied from a psychoacoustic point of view as a function of the particular variable being measured, and (c) under simulated arctic conditions, the experimental masks offered far better protection of the wearer's skin than did the standard mask.

Introduction

For many years, the Army has employed face masks to protect personnel from cold, wind, and blowing snow in environments in which the ambient temperature is as low as -65°F with windspeeds of up to 35 mi/hr. These cold weather face masks are worn in conjunction with the cold-dry uniform and their chief purpose is prevention of frostbite. However, the designs of face masks must be such that they do not unduly impair the wearer's performance by affecting field of vision, hearing, speech intelligibility, and mobility of the head and neck. Furthermore, the masks must be compatible with the standard cold-dry uniform, helmets, communication equipment, glasses and goggles, rifles, and other clothing and equipment in general field use.

Since World War II, a number of face masks have been developed and tested in attempts to meet these design requirements. During World War II, the only face protection device available for Army use was a knitted toque which fit snugly over the head and had an opening for the eyes. It offered no protection from the wind and became moist with expired air from the breath. Thus, the toque was considered to be hazardous under certain environmental conditions and efforts were directed toward development of face masks made of air-impermeable materials (Ref. 1).

The present Army standard cold weather face mask was developed out of these efforts (Fig. 1). It consists of two layers of felt-like material covered with an olive-drab, windproof material similar to oil cloth. There are apertures for each eye, the nose, and the mouth. The latter is covered by a piece of material which snaps in place. As can be seen in Figure 2, there are two restraining straps which run around the back of the head and must be snapped to hold the mask firmly against the face. Glasses and goggles are worn outside the mask and their bridges must span its nasal portion. The stems of glasses may be placed through the temporal portions of the eye apertures and extended back to the ears under the mask. Among the deficiances identified in the standard mask during field use are: poor low temperature characteristics, poor fit among a cross-section of the U.S. Army population, interference with vision among some personnel, lack of stability in a dynamic environment, and poor compatibility with goggles and glasses (Ref. 2).

An overview of prototype mask designs which were developed through 1957 and evaluated as replacements for the standard cold weather face mask has been prepared by McGinnis (Ref. 1). Among those field-tested up to that time were the Coldbar and the Wood-Hafferty masks. The former was made of a plastic foam material which was wind- and water-impermeable. However, this mask was found to restrict the wearer's field of vision and to be incompatible with glasses. The Wood-Hafferty mask combined an air-tight compartment around the nose and mouth with a well-ventilated, double layer, transparent face piece which permitted a wide field of vision and was held away from the face. It also incorporated a partial heat-regenerating system whereby inhaled air was pre-warmed by exhaled air. In field tests at Fort Churchill, Manitoba, Canada, the Wood-Hefferty mask was found by observation and interview of the wearers to be superior to the Coldbar, but it was not compatible with rifle sights and sometimes made breathing difficult (Ref. 1).

Another cold waather face mask field test was conducted in 1965-66 on a porous nonwoven fabric designed to cover the mouth and nose (Ref. 3). This oronasal barrier was fastened to the head by use of an adjustable headband. The barriers were commercially-available, respiratory devices and were similar to the Wood-Hafferty system insofar as they were designed to warm and humidify inhaled air. They were tested by armored vehicle and infantry personnel at a minimum temperature of -50°F with windchills of up to 2250 kg-cal/m^2/hr. It was found by observation and interview of the users that the oronasal barriers offered partial face protection under these environmental conditions and were compatible with standard arctic clothing and headgear, including the combat vehicle crewman's (CVC) helmet and communication equipment. However, the barriers did become saturated with moisture and tended to freeze. This made breathing difficult. They also caused fogging of glasses and goggles and were difficult to don and doff with arctic mittens (Ref. 3).

In 1965, a cold weather face mask under development by the Canadian Military Service was field-tested in Alaska (Ref. 4). This was a stretch-type mask made of polyurethane foam with apertures for the eyes, mouth, and nose. The mask was found to offer good protection from the wind and snow and fit the military wearers well except for some looseness in the chin area (Ref. 4).

The next and latest activities in cold weather face mask design were directed toward development of a prototype mask which incorporated the desirable features of the Canadian mask and the oronasal barrier. This effort culminated in the development of two prototype face masks of identical design which differed with respect to the insulating material used (Ref. 2). Both were constructed of laminates of insulating material sandwiched between stretch nylon on the outer surface and cotton jersey on the inner surface. One prototype (experimental mask I) incorporated a 1/4 in. thick, open-cell, polyurethane foam as the insulating layer, while the other (experimental mask II) had a 3/8 in. thick layer of polyester batt (Ref. 2).

The prototypa was designed as a one-piece, close-fitting mask in a single size which is adjustable to fit the range of haad and face dimensions typical of the U.S. Army male population. It incorporates (a) tha commercially-available, oronasal barrier previously tested (Ref. 3) to prevent the inhalation of low temperature ambient air, (b) an insulating face piece which covers the forehead, cheeks, nose, ears, and chin and (c) a retantion harness (Raf. 2).

As can be seen in Figure 3, there is a singla visual aperture. A 1/4 in. wide, 1-1/4 in. long elastic strap connecting the upper and lower edges of the visual port is used to aid in keeping glasses in place and to preserve the port opening. There is a padded stiffener bar on tha inside of the mask along the bridge of the nose and under the visual port. The malleable bar permits the mask to be molded to fit snugly against the nose and the face; its purpose is to prevent moist exhaled air from rising into the visual port causing glasses or goggles to fog.

The oronasal barrier is attached to the face piece by use of hook and pile fastener tape and can be completely removed (Fig 4). . The barrier is edged with malleable wire to permit formation of the barrier to the contours of the oronasal portion of the face.

Adjustment of the mask to a range of head and face sizes is accomplished by a strap under the chin, while adjustments for head circumference variations are incorporated into the head harness. This harness consists of a single overhead strap sewn to the upper edge of the face piece and to the center of a single back strap (Fig. 4). One end of the back strap is sewn to the edge of the face piece at one side, while the other end attaches to the other side of the mask by use of hook and pile fasteners.

Loops are provided on either side of the face piece to hold glass stems (Fig. 5). The bridges of glasses can be held in place on the bridge of the nose by slipping the glasses under the elastic strap of the visual port.

Details of the design, fabrication, and engineering testing of the prototype cold weather face mask are presented in Reference 2 and results of an informal field evaluation of this item at a minimum temperature of -35°F with a 10 mi/hr wind are presented in Reference 5. Because the results of the limited field test were favorable, the present study, a more extensive human factors investigation of the prototype mask, was initiated. Three types of cold weather face masks (the standard, experimental mask I, and experimental mask II) were evaluated in four series of tests:

1. Visual field investigation
2. Psychoacoustic investigation
3. Pre-chamber testing
4. Arctic chamber testing

The methods, results, and discussions of the findings of this evaluation of cold weather face masks are presented in this report.

I. Visual Field Investigation

Purpose – The purpose of conducting this test was to determine the limits of the visual field for each cold weather face mask being evaluated. The technical characteristic being addressed in this test is: "The system shall not restrict...field of vision to a degree greater than current field clothing and equipment." (Raf. 6, Para 7d).

Subjects – Three test subjects were selected at random from the CRL* Test Subject Platoon with the restriction that the subject did not require corrective lenses.

Procedure – Measurements of the visual field were made on a Ferree-Rand Perimeter under a fixated eye condition. The subject fixated one eye on a central target, while the other aye was blindfolded, and detected a target moving in from the periphery. The target to be detected was a white dot with a diameter of 6 mm which subtended a visual angle of 1°. The measurements were made monocularly for each eye for each of the eight areas of visual field: temporal, super-temporal, superior, super-nasal, nasal, infero-nasal, inferior, and infero-temporal.

The visual field of each subject was measured under the following conditions: no mask, standard mask, experimental mask I, and experimental mask II. The subject did not wear any other arctic equipment, goggles, or glasses during this test.

Results and Discussion – Figures 6 and 7 are plots of the mean visual field for the right eye and the left eye, respectively, under the conditions of no mask, standard mask, experimental mask I, and experimental mask II. The means were obtained by summing over the data of all subjects. In Figure 8 the measurements from each eye were combined (reversing portions of the visual field for the left eye, as required) to obtain one mean value for each of the eight areas of the visual field.

It can be seen that all three face masks restrict the nasal, infero-nasal, inferior, and infaro-temporal portions of the visual field of each eye when compared to the no mask condition. This is attributable to the protrusion of the oronasal portions of the masks into tha visual field. In each figure presented, there are some portions of the superior region of the visual field that are increased whan a face mask is worn. According to reports from the subjects who participated in the test, this anomaly is due to the reflection of the target off the face mask and into the eye. This resulted in the target sometimes being seen at a greater eccentric angle when a mask was being worn.

A comparison of the visual field obtained with each of the three face masks indicated that the standard mask restricted the nasal and infero-nasal portions of the visual field more than did the experimental masks (Figure 8). The restriction of the inferior and infaro-tamporal portions was greatest when experimental mask I was worn (Figures 6 and 8). This is probably due to the fact that the material in this mask was thicker and bulkier than that in the other two masks.

*Climatic Research Laboratory

In generel, both experimental masks meet the technical requirement of not restricting the field of vision to a greeter degree than the standard mask. Furthermore, the visual fiald with experimental mask II was slightly greeter than with experimental mask I or the standard mask.

II. Psychoacoustic Investigation

Psychoacoustic test of sound ettenuetion end speech intelligibility were conducted to determine the stand-alona performance of the masks, and their compatibility with existing vehicle crewman's helmets.

Four experiments were performed to enswer the following questions:

a) How do these masks affect the auditory acuity of the soldier?

b) How do these mesks affact speech intelligibility in face-to-face communication?

c) How do these masks affact the acoustic attenuation provided by a modern helmet system?

d) How do these masks affect speech intelligibility with electrically aided communication via helmet-mounted commo sets?

e) Is the decrement in speech intelligibility while wearing the mask attributable to the talking or the listening end of the system?

A. Auditory Acuity

Purpose – It is reasonable to axpect that any materiel which covers the soldier's ears will attenuate environmental sound to some degrea, thereby reducing his auditory acuity. Both the standard end tha experimental II masks were tested to datermine the amount of attenuation they added to a cold weather uniform consisting of a pile cap and perka hood.

Subjects – The subjects were four members of the Bahavioral Sciences Division steff.

Procedure – The subjects were seated in an acoustically isoleted chamber (Industriel Acoustics Corp. Model SR40.4) one meter in front of and on tha axis of a loudspeaker (Klipschorn). An Audiometer (Genaral Radio Model E-800) was connected to the loudspeaker. The subject hald a control switch for the eudiometer in his hand. The threshold shift method was used to measure attenuation, following the recommendetions of the American Standards Associetion Specification Z24.22-1957, Method for the Measurement of the Real-Eer Attenuation at Threshold.

Each of the four subjects tracked his audiogram three times under each of four conditions: 1) head bare, 2) pile cap and hood, 3) pile cap, hood, and standard mask, 4) pile cap, hood, and experimental mask II.

Results and Discussion – The results were tabulated by averaging threshold values across subjects and repetitions for each condition at nine discrete frequencies. The results are presented in Table 1. As expected, experimental mask II produced more undesirable attenuation than the standard mask or no mask conditions. Attenuation was greatest for the higher frequencies. The extent to which this attenuation will impair the performance of the soldier's mission is difficult to predict. Experiment B shows that speech intelligibility (under the conditions measured) does not suffer when experimental mask II is worn. It is probable that the soldier's ability to detect and localize faint, high frequency sounds (a twig snapping, for example) will be reduced when experimental mask II is worn.

B. Speech Intelligibility, Face-To-Face

Purpose – The purpose of this experiment was to determine the extent to which the standard and experimental II face masks affect the ability of the soldier to converse with others under normal noise conditions.

Subjects – The subjects were four members of the Behavioral Sciences Division staff and were the same subjects used in Experiment A. The subjects were randomly assigned as two, two-man teams.

Procedure – A team of subjects was seated in the same acoustic chamber used in Experiment A. One man was designated a talker, and his teammate was designated as a listener for each trial. These roles were reversed according to a counterbalanced test plan. A trial consisted of the talker reading a list of 50 phonetically balanced (PB) words, which the listener wrote down as best he could. The talker sat 1 meter to the right of the listener, and faced the listener's right side. A noise (65 dBC, white lo-passed at 6KHZ) was present during all trials to simulate normal room noise. Each subject served in each role twice under each of the following conditions: 1) pile cap, and parka hood, 2) pile cap, parka hood, and standard mask, 3) pile cap, parka hood, and experimental mask II. Both team members wore the same uniform configuration on a given trial. The order in which conditions were presented was counterbalanced. The subjects were familiarized with alternative forms of the word lists and with the test procedure prior to data collection. The score for each trial consisted of the percentage of words correctly received.

Results and Discussion – The results were tabulated by averaging the percentage scores across all subjects and repetitions for each condition. The results are presented in Table 2. The chi-square test was used to test the significance of these results, as well as the results of Experiments D and E. The standard mask resulted in poorer speech transmission than either experimental mask II or no mask. This is probably due to the interference between the standard mask and the talker's lips, which impaired articulation.

Because of the nature of the of the PB word lists, and the total absence of context in the one word messages transmitted, a score of 70% correct is generally considered adequate for communication of messages involving sentences and context. All systems measured met this criterion.

C. Helmet Attenuation

Purpose – The purpose of this experiment was to determine the extent to which these masks affect the acoustic attenuation provided by a modern crewman's helmet.

Subjects – The subjects were four members of the Behavioral Sciences Division staff, and were the same subjects who served in Experiments A and B.

Procedure – The test procedure was identical to the procedure followed in Experiment A with the exception that the SPH-4 helmet was worn over the masks and over the subject's bare head. The parka hood was not worn during this experiment.

Results and Discussion – The results are presented in Table 3. Both masks reduced the desirable protective attenuation provided by the SPH-4, probably because the mask material or fastening straps defeated the acoustic seal between the earcups and the subject's head. Experimental mask II produced the poorest attenuation, especially at lower frequencies. Crewman who must wear either mask in a high noise environment should be instructed to wear insert ear plugs to reduce the possibility of permanent, noise-induced hearing loss. It would seem desirable to develop a mask designed specifically for use with crewman helmets. Such a design could use existing helmet suspension to hold an abbreviated mask, which need cover only the facial areas not protected by the helmet.

D. Communication Intelligibility

Purpose – The purpose of this experiment was to determine the effects of these masks on speech intelligibility with electrically aided communication via helmet mounted commo sets.

Subjects – The subjects were four members of the Behavioral Sciences Division staff, and were the same subjects used in Experiments A, B, and C. The subjects were randomly assigned to two, two-man teams.

Procedure – The procedure was identical to that used in Experiment B with the exception that the noise level in the test chamber was raised to simulate the acoustic environment of a moving tank. A pink noise source lo-passed at 6KHZ, and presented at a level of 100 dBC overall, was employed for all conditions.

The listener wore an SPH-4 helmet in conjunction with the standard and experimental II masks, as well as with no mask. The talker wore an APH-5 helmet under the same conditions, and the talker and listener wore identical masks for each trial. The APH-5

was used for the talker since a sufficient number of SPH-4 helmets was not available. Both helmets were connected to standard aircraft interphone amplifiers, and the subjects were instructed to adjust the amplifier volume controls to provide what they considered to be the best reception. Then, as in Experiment B, phonetically balanced word lists were transmitted.

Results and Discussion – The data are presented in Table 4. The experimental mask resulted in intelligibility scores below the 70% criterion of adequacy. The standard mask showed no decrement in intelligibility. The poorer performance with the experimental mask could come from two sources. First, the talker's microphone can not be positioned close to his lips, and this no doubt reduces the signal to noise ratio at the microphone output. Second, the poor acoustic seal between the earcups and the listener's head both admits environmental masking noise and leaks signal energy thus reducing the signal level at the listener's ear. An additional experiment was conducted to determine which of these factors contribute to the observed decrement.

E. **Locus of Speech Intelligibility Decrements**

Purpose – The purpose of this experiment was to determine whether the decrement in speech intelligibility observed with the experimental mask was due to effects at the talking or the listening end of the system.

Subjects – Eight military test subjects from the CRL test subject platoon were used.

Procedures – The procedure was identical to that followed in Experiment D, with the following exception: one of the experimental masks was modified by cutting a 2.5 cm slit in the left side of the oral-nasal barrier. The purpose of the slit was to allow the microphone boom to be positioned inside the barrier, in close proximity to the talker's lips. The experimental design called for the following conditions: 1) Talker with microphone outside barrier: listener wearing experimental mask under the SPH-4, 2) Talker with microphone inside barrier: listener wearing experimental mask under the SPH-4, 3) Talker with microphone outside barrier: Listener wearing no mask under the SPH-4, 4) Talker with microphone inside barrier: listener wearing no mask under the SPH-4.

Results and Discussion – The results are shown in Table 5. No difference was found which could be attributed to microphone placement – a surprising finding considering the known performance characteristics of noise-cancelling microphones. It is possible that the geometry of the barrier slit and microphone boom did not permit optimal orientation of the microphone, and negated the possible improvement due to lip to microphone distance reduction.

A large and highly significant effect was found which is attributed to the listener wearing a mask. This lends support to the hypothesis mentioned above: the decrement in performance is due to noise-masking and signal leaks. This decrement, like the decrement in protective attenuation, could be eliminated by redesigning the mask to limit its coverage to frontal facial areas.

III. Pre-Chamber Testing (Personal and Equipment Compatibility)

Purpose — The purpose of this test was to evaluate the three types of cold weather face mask with regard to ease of donning and doffing, compatibility with CVC and infantry helmets, ability of the wearer to perform bodily functions such as drinking, spitting, etc., and compatibility with weapon operation and standard arctic clothing. The technical characteristics being addressed in these tests are: "The design and construction of the mask shall be such that it is compatible with the use of any weapons or equipment listed in the Military Characteristic" (Ref. 6, Para. 7c). "The mask shall be designed so as to permit maximum ease of donning and doffing...The system shall permit simple adjustment or adaptations without assistance to various levels of physical activity, body functions, and environmental conditions." (Ref. 6, Para. 7e and 7f).

Subjects — Nine test subjects were selected at random from the CRL Test Subject Platoon. These same subjects also participated in the Arctic Chamber testing.

Procedure — The subject was given one of the three types of cold weather face mask, and standardized donning instructions were read to him while he donned the mask. No mirror was used. The subject was then permitted to don and doff the mask several times in order to familiarize himself with the operation and the fit of the mask was checked.

The subject was next asked to drink water from a glass and he was also permitted to smoke. He was asked if the mask became wet, and if he would find it difficult to blow his nose or eat while wearing the mask.

While wearing fatigues and a mask, the subject was asked to lie prone, sight a target with a rifle, and indicate when he was ready to fire. The time to prepare to fire was recorded and the subject was given three trials at this task.

The subject was then outfitted in a field jacket with liner, arctic parka with liner, arctic hood, pile cap, and arctic mittens with liner. He was asked to remove the hood and the pile cap, don the face mask, the pile cap, and the hood while keeping on the mittens. The time to don the face mask, the cap, and the hood was recorded and the mask fit was checked. The subject then removed the hood, pile cap, and face mask and repeated the mask donning task two more times. The arctic mittens were replaced by the wool insert from the trigger finger mittens and the subject performed the donning task again three times. The data from the donning tests were subjected to analyses of variance to determine if the type of mask significantly affected donning time.

After completing this testing, the subjects donned the CVC helmet and the infantry helmet with liner while wearing the face mask. The subjects then completed a questionnaire (Appendix A) regarding the tasks performed.

Each of the nine subjects completed the above procedure on three separate days. Each time, the subject wore a different type of face mask. The order of presentation of the types of masks was randomized among subjects. The subjects wore the same mask in the chamber testing which followed.

Results and Discussion — The results of the Pre-Chamber Testing will be presented in the same order in which the tasks were performed as outlined in the procedure. The answers subjects gave in response to the "Pre-Chamber Questionnaire" (Appendix A) will be presented as they pertain to each task; the tabulated data from this questionnaire is presented in Appendix D.

Familiarization with the Mask — All subjects in all mask conditions reported that the instructions for donning the mask were clear (question 1a). The majority of the subjects under each of the separate mask conditions reported that the mask fit comfortably; only 2 subjects of the 9 reported that any of the masks were uncomfortable — both of these thought that the standard mask was uncomfortable (question 1b). It was observed that the three types of masks fit all subjects properly. Some subjects could snap the lower restraining strap of the standard mask only because it had been lengthened.

Performance of Personal Body Functions — While none of the 9 subjects reported that either of the experimental masks interfered with their ability to drink water from a glass, 3 of the 9 reported that the standard mask did interfere (question 8a); furthermore 2 of these 3 subjects found that the standard mask became wet when they tried to drink water from the glass (question 8c). When they were asked to spit out water while wearing the mask, only one subject while wearing experimental mask I and one subject while wearing the experimental mask II reported difficulty. When asked to spit out water while wearing the standard mask, however, 4 of the subjects reported that they had difficulty (question 8b).

When asked to predict their ability to eat while wearing the mask (question 10), most subjects (>67%) reported that they could do so regardless of which mask they were wearing.

Of those subjects who smoked, all found that the mask produced little or no interference with smoking (question 9). However, the investigators observed that the subjects appeared to have more difficulty "lighting up" while wearing the standard mask. This was probably due to the large nose piece on the mask.

With respect to the ability to blow the nose while wearing a mask (question 11), most subjects (>89%) predicted that they would hava no trouble. Only 3 subjects actually had the occasion to blow their noses. However, all 3 did so while wearing axperimental mask I. Of these 3, one was unable to do it while wearing tha mask; he reported that there was not enough room to hold his handkerchief and blow at the same time.

Weapon Compatibility – The rifle subjects used for sighting a 1-1/2" target at 30 feat was an M-14. The subject lay prone. At the signal the subject picked up the rifle, sighted the target, and pullad the trigger. Tha subject's "time to fire" was measured by recording the time interval between the "Go" signal and tha "click" of the trigger mechanism. The "time to fire" scores for the last trial were subjected to a two-way analysis of variance (masks X Ss). The data for the analysis are presented in Table 6 and the ANOVA results are presented in Table 7. Tha results of the ANOVA indicate that the mean "tima to fira" scores wera not significantly different from one another as a function of which mask the subjects were wearing. The average time to fire for all subjects regardless of which mask was worn was 3.59 seconds.

Post-experimentally, none of the subjects reported that the experimental masks interfered with their being able to sight with the rifle. However, 3 of the 9 subjects reported that the standard mask interfered with this task somewhat.

Donning the Mask. – Since each subject was required to don each of the 3 masks whila wearing first the arctic mittens and then only the trigger-finger woolen inserts, the scores for the length of time it took each subject to don the masks were subjected to a 3 way analysis of variance (Ss X masks X gloves) with three trials (observations) per cell. The data for the ANOVA are presented in Table 8 and the summary of the ANOVA is prasented in Tabla 9. The results indicated that (a) it takes longer for each subject to don the standard mask that it does aither of the experimental masks, (b) it takes longer to don a mask if arctic mittens ere worn as compared to the trigger-finger woolan inserts alone, (c) subjacts vary significantly from each other with respect to the average time it takes to don a mask, and (d) the type of mask one must don and the type of gloves one is waaring interact (invariably the subject could not don the standard mask while wearing the arctic mittens).

Tha results of this ANOVA are reflected in the responses to questions 2 and 4 on tha questionnaire. All tha subjects reported at least some difficulty or "much difficulty" whila trying to don all three types of masks when wearing the arctic mittans. As already reflacted in the ANOVA, it was observed that the subjects found it impossibla to don the standard mask with the arctic mittens; this complete inability to don tha mask was due to the fact that the standard mask snaps could not be fastened while the subject wore tha arctic mittens. It was noted, however, that subjects could grasp and fasten the velcro tabs on the experimental masks aven though they were wearing the arctic mittans. The subjects using the standard masks serendipitously discovered that they could overcome

the snap-fastening problem by fastening the top snap *before the trial began*. In this way they simply slipped the mask over the head and did no fastening on the bottom snap at all. This procedure resulted in the subject being able to cover his face with the standard mask, but the fit was quite loose.

Although the majority of the subjects reported at least some difficulty donning the masks while wearing the woolen inserts, 2 subjects reported that donning the experimental mask I was "easy". Subjects using the standard mask found that they could fasten the snaps using the woolen inserts, but that it was still a very difficult chore.

Clothing Compatibility — With only one exception (one subject wearing experimental mask I) *all subjects* reported that they judged there to be no interference of the mask (any of the 3 masks) with the wearing of the pile cap and hood (question 6). In addition *all subjects* reported that the masks could be worn with either the CVC or infantry helmets.

Conclusions (Pre-Chamber Testing) — Pre-chamber testing indicated that, although there were only slight advantages of the experimental masks over the standard masks (with respect to comfort, ability to drink, ability to spit, and ability to smoke), the experimental masks proved far superior to the standard mask when one considers a maximum ease and speed of donning the mask while wearing arctic clothing. All masks were virtually equivalent performance-wise with respect to rifle aiming, ease of eating, and ease of blowing the nose.

IV. Arctic Chamber Testing

Purpose — The purpose of this test was to evaluate the three types of cold weather face mask with regard to wearer comfort, degree of protection, and amount of frosting and fogging. The technical characteristics being addressed in these tests are: "The mask, when used with the cold-dry uniform shell protect the wearer's face from cold, wind,...and frostbite. The configuration...of the mask shell...provide optimum fit and comfort." (Ref. 6, Para. 7e). "Configuration and construction of the mask shall provide adequate environmental protection to inspire acceptance and confidence during use." (Ref 6, Para. 7b). "The mask shall be designed so that it will be capable of being worn with cold weather headgear with or without goggles. The system shall not restrict...breathing to a degree greater than current field clothing and equipment." (Ref 6, Para. 7d).

Subjects — Nine test subjects were selected at random from the CRL Test Subject Platoon. These same subjects also participated in the Pre-Chamber testing.

Procedure — Each subject was equipped with a thermocouple harness. Thermocouples were taped on the forehead, the left cheek, the tip of the nose, and below the left eye. There was also a thermocouple on the right little finger and the right big toe. The subjects were dressed in standard arctic clothing consisting of insulated arctic

boots, field trousers with liner, arctic trousers with liner, wool shirt, field jacket with liner, pile cap, arctic parka with liner, arctic hood, and arctic mittens. The ruff of the hood was folded back. In addition, the subject wore a cold weather face mask with either glasses (sun or corrective) goggles, or no eye protection.

The subject was then exposed to a temperature of -50°F and a windspeed of 10 mi/hr for one hour. (Windchill = 2209.92 kg-cal/m^2/hr.) The subject sat facing the wind during the initial 15 minutes of low temperature exposura. For the next 30 minutes, he walked on a treadmill at a speed of 2.5 mi/hr while facing the wind. He again sat facing the wind for the final 15 minutes. Upon leaving tha chamber, the subject fillad out a questionnaire (Appendix B). On the final day of testing, he complated an additional questionnaire (Appendix C).

Each of the nine subjects completed the above procedure on each of three separate days. Each time, tha subject wore a different type of face mask. The order of presentation of the types of masks was randomized among subjects. The nine subjects were divided into three eya protection groups: no protection group, glasses (sun or corrective) group, and goggle group. Each subject was exposed to only one level of aye protection throughout the testing.

The four face temperatures, the digital temperature, and the toe tamperature were recorded during each chamber test. The digital and the toe temperatures were monitored as a safety precaution and any subject with a temperature of 39°F or lower was to be removed from the chamber. The face temperature from each of the four locations was subjected to a separate analysis of variance to determine if there was a significant difference in the degree of warmth provided by the three types of face masks and if this was affected by the type of eye protection worn and the duration of cold axposure. The raw data for the temperature analyses were the lowest temperatures achiaved at each location per 5 minute period.

During the chamber tests, observations were made regarding the occurrence of fogging of the eye protection devices, the accumulation of frost on any portion of the mask, the necessity and the reason for removal of the oronasal portion of the mask, and the effectiveness of shaking as a method for removal of frost forming on the oronasal portion. Upon termination of tha chamber tests, each mask was inspected for moisture and cleanliness.

Results and Discussion

Face Temperature Measure — No subjects had to be removed from the chamber because of low facial, digital or toe temperatures. *All three types of face masks maintained facial temperatures at higher levels under these ambient temperature and windspeed conditions (-50°F, 10 mi/hr) than would have been achieved without any protection to the face.* Facial temperatures generally remained above 70°F. Tha axceptions occurred

in the areas of the nose and the eye when the standard mask was used. Under this face mask condition, nose temperatures achieved a low point of 66°F and eye temperatures of 58°F were recorded. However, these were extremes and the mean temperatures with the standard mask at both these facial locations were above these minima. The presentation of further results of the statistical analyses performed on the skin temperature data will emphasize whether or not the masks differed significantly from each other in the amount of protection given.

The data from the sitting phase and the treadmill phase for each of the four facial thermocouple locations were subjected to separate analyses of variance. The design applied to the former was a hierarchial one: Subjects (1-3) by Time (0-15 min) by Phase (1-2) by Mask (Standard, Experimental I, Experimental II) within Eye Cover Group (None, Glasses, Goggles). The design for the analysis of the treadmill phase data was also a hierarchial one of the form: Subjects (1-3) by Time (0-30 min) by Mask (Standard, Experimental I, Experimental II) within Eye Cover Group (None, Glasses, Goggles).

The analyses performed on the forehead and the cheek data indicated that the temperatures at these two locations did not differ significantly as a function of the type of mask worn. During the first 15 min of cold exposure (first sitting phase), the temperatures of the forehead and the cheek decreased significantly and at approximately the same rate for all masks. For the next 30 min of cold exposure, the subjects walked on the treadmill. During this time, the forehead and the cheek temperatures remained relatively constant and were equal to those attained at the end of the first sitting phase. Forehead and cheek temperatures during the final 15 min of exposure (second sitting phase) again decreased significantly to levels lower than those at the end of the first sitting phase. The lowest mean temperature of both the forehead and the cheek was approximately 71.5°F. This was achieved at the end of the 60 min cold exposure.

The analyses of variance performed on the temperature data obtained from the tip of the nose and from the skin surface below the right eye yielded significant effects attributable to masks. The results of the analyses of variance performed on the data of these two temperature points are presented in Tables 10 and 11. *The masks did differ significantly in the amount of protection offered these two locations.* It should be noted that the thermocouple below the eye was placed such that it was underneath the stiffener bar of experimental masks I and II.

At the tip of the nose, the temperatures achieved with the standard mask were significantly lower than those obtained with either experimental mask I or II. The temperatures maintained with the two types of experimental masks were approximately equal (Figure 9). This finding regarding the differential effects of the face masks is attributable to the protection offered by the oronasal portion of the experimental masks which is lacking in the standard mask. The mean temperature was 72.0°F when the standard was worn, 81.8°F with experimental mask I, and 82.7°F with experimental mask II.

During the first sitting phase, nose temperature decreased regardless of the type of mask being worn, but the decrease was greater with the standard than when either of the experimental masks were worn (Figure 9). During the 30 minutes thet the subjects walked on the treadmill, the mean skin temperatures of the nose increased significantly so that they were equal to or slightly greater than those at the beginning of cold exposure. The tempereture increase during the walking phase was greatest when the standard mask was worn, but the temperature level with this mask remained below that achieved when either experimental mask was worn. During the second 15 minute sitting phase (after 45 minutes of cold exposure), nose temperature again decreased to e level equal to or slightly lower than thet achieved at the end of the first sitting period. Again, the greatest decrease occurred when the standerd mask was worn (Figure 9).

As was mentioned above, the type of face mask used also significantly affected the temperature of the skin below the right eye. The overall mean temperature with the standard mask was 63.7°F. It was 79.0°F when experimental mask I was worn and 74.9°F with experimental mask II. Although the mean temperature level achieved with the standard mask was significantly lower than that with either of the experimental masks, the levels attained with the latter did not differ significantly from each other.

Temperature below the eye decreased significantly during the first 15 minute sitting phase regardless of the type of mask worn, but the temperature decrease was greatest with the standard mask (Figure 10). Throughout the 30 minute walking phase, the temperatures remained relatively constant at levels equal to or less than those attained at the end of the first sitting phase. Again the standard mask yielded the lowest temperatures. Temperatures during the second sitting phase were significantly lower than those during the first, but were relatively constant over the 15 min period (Figure 10).

The effect that the type of eye cover may have on facial temperatures was also analyzed. It was found that the type of eye cover worn (None, Glasses, or Goggles) did not significantly affect facial temperatures at any of the four thermocouple locations. This is probably attributable to the fact that all thermocouples were placed under the masks.

Arctic Chamber Test Observations — The following is a summary of observations made by the investigators during the Arctic Chamber Test. Observations were made regarding the occurrences of fogging of the eye protection devices, the accumulation of frost on any portion of the mask, the necessity and reason for removal of the oronasal portion of the mask, and the effectiveness of shaking as a method for removal of frost forming on the oronasal portion. Table 12 presents a summary of the observations made with respect to each of the three masks tested.

Eye Cover Fog — It can be seen that there were no observable differences between the three masks with respect to the fogging or frosting of eye cover. In general, subjects with goggles/glasses had begun to have a fogging problem while wearing the standard mask within the first 5 minutes of the test. Virtually every subject wearing goggles/glasses, regardless of the type of mask being worn, had them fog over completely and then frost within the first 15 minutes of the test (i.e., the subjects were often "blinded" by the time they were to be put on the treadmill). When the goggles/glasses were not put on until the moment of entry into the cold chamber, total fogging and then frosting with the experimental masks did not occur until 15 minutes of treadmill time had expired (therefore, 30 minutes into the test). With the standard mask, total fogging and frosting still occurred before the end of the first 15 minutes of the test.

For one subject who wore goggles (with experimental mask I), complete fogging did not occur during the entire test. Nevertheless, in general, subjects with goggles/glasses were blinded within the first 30 minutes of the test regardless of the type of mask worn. The amount of frost which accumulated on glasses was thicker with the standard mask. Subjects with no eye protective wear had frost form on their eye lashes and brows (when exposed); this oftentimes became quite uncomfortable, but vision remained better than if the subject had worn goggles/glasses.

Oronasal Frost — For all three masks, oronasal frost occurred within the first 10 to 15 minutes of the test, rarely hampered breathing, and could easily be brushed off with the arctic mitten. Subjects had much difficulty removing the oronasal portion for "shaking" purposes while they were wearing the arctic mittens; they found that they could more easily remove the frost by simply brushing it off with the arctic mitten.

One problem which arose with the standard mask (and not the experimental masks) was the fact that frost formed in the "cavity" portions of the nose and mouth pieces; bare skin was exposed at these "cavity" portions of the mask.

After the test, all masks were inspected. It was found that the oronasal portions (nose and mouth pieces of the standard mask) and chin areas of all three masks were wet; the rest of the mask varied from dry to damp. Wetness was probably enhanced by the fact that some of the frost must have melted during the time the subjects exited the Arctic Chamber, moved to the arctic dressing room, and removed their masks.

Each of the three masks worn was washed at the completion of each chamber test. Since there were three of each type of masks available for use in the study, each mask was washed three times. The washing was done by hand using mild soap. The masks were dried at room temperature. It was found that the standard mask appeared unsoiled after use, but that the lining of the experimental marks in the area of the stiffener bar did become soiled. This was easily removed with immersion and some rubbing in the soapy water. The oronasal portions of the experimental masks were put in the water for washing and were not adversely effected by it.

The standard mask dried at room temperature in about 18 hours. Experimental mask I required about 16 hours and experimental mask II dried in about 12 hours. After drying, the outermost, windproof layer of the standard mask appeared "puckered" when compared to a mask which had never been washed. This was the only noticeable change in the masks attributable to washing.

The only sign of wear in any of the masks appeared in one of the three experimental I masks used. Here, the cotton jersey inner surface pulled away from its stitching.

Post-Chamber Questionnaire — The results of the Post-Chamber Questionnaire (Appendix B) will be presented in the following manner: The tabulated data from the questionnaire are presented in Appendix E and the following discussion will refer to these data by topic area (rather than the order in which the questions were asked). Each question will be referenced by number in order that the reader will have easy access to the tabulated data.

The Mask as a Protective Device (Question 1-7): When asked to judge the effectiveness of the masks as a screen against the wind, most subjects rated all three masks average, good, or excellent. Two of the 9 subjects reported the standard to be "Fair" or "Poor" respectively; none did so for experimental mask I, and one rated experimental mask II as "Fair".

In line with these answers, most reported that the face was "about the right temperature" or "warm". This finding was also reflected in the temperature data. There was only one rating of "very cold" that was for the standard mask. Subjects uniformly agreed that the face was warmer when they were on the treadmill than when they were sitting. This was also reflected in the temperature data.

In agreement with the investigators' observation, all subjects were aware of the frost which had formed on their masks.

Under each of the three mask conditions, only 2 of the 9 subjects reported that their faces became wet under the mask. The others reported that their faces were dry.

Mask-Eye Wear Compatibility (Questions 9, 10, and 11): In general agreement with the investigators' observations, those subjects who wore glasses/goggles reported that at least some portions of the glasses/goggles fogged. While 84% of the subjects wearing either the standard or the experimental mask I reported that all portions of their goggles/glasses fogged during the test, only 50% of the subjects wearing the experimental mask II reported complete fogging. Apparently, when the investigators judged the subjects to be "blinded", some subjects were only partially blinded by fogging. However, in agreement with the independent observations, complete fogging occurred by the time the test was half completed.

While all subjects wearing glasses agreed that the glasses should *never* be worn with the cold weather face mask (regardless of whether the mask was the standard or the experimental type), the other subjects were split in their opinion as to whether the goggles should be worn. Apparently, it took longer for the goggles to fog and they protected the eyes from the wind better.

Effects on the Oronasal Portions of the Masks (Questions 12-18): None of the subjects answers to these questions discriminated between the three masks. That is, the following discussion of the characteristic effects on the oronasal portion of the masks pertains to all three masks, standard as well as experimental.

In general, the subjects very rarely had breathing difficulties due to the oronasal portion of the mask which covered their mouth and nose. Consequently, most subjects reported that they did not attempt to remove the oronasal portion of the mask. When the frost formed, and they wanted to remove the frost, they simply brushed it off with the arctic mitten rather than remove the oronasal portion and shake it. Most subjects reported that they seldom attempted to shed the frost.

The subjects seemed to be split in their opinion as to whether the oronasal portion of the mask ever got wet. This may be due to the fact that, during the cold exposure, it was frost covered and that they could not judge the amount of wetness until they got back to the dressing room. In the dressing room the frost melted rapidly and could be an extraneous factor in producing the "wetness".

In general, the subjects reported that the frost which formed on the oronasal part of the face mask was easy to shed and caused little or no discomfort.

Mask Comfort (Questions 7, 8, and 9): The frequency of reports that the mask felt "heavy" were not numerous (1 of 9) and did not differ as a function of which of the three masks the subject was wearing.

The same was true of subjective reports with respect to adverse skin effects produced by the mask. With the exception of one report that the standard mask felt "itchy" and one report that experimental mask II "hurt the chin", all subjects reported no adverse effects.

However, 44% of the subjects regarded the stiffener bar of the experimental masks as being somewhat of a bother. The standard mask has no stiffener bar.

General Comments (Questions 20, 21, and 22): When asked to specify their special likes about each of the masks, most subjects did not make comments which differentiated between the three masks. All liked the masks because they were "warm". When asked to specify their dislikes, however, the subjects reported that their nose was colder when wearing the standard mask than when wearing one of the experimental masks.

In general, subjects reported that, regardless of which mask they wore, their face was at least "fairly comfortable".

Final Overall Rating by the Subjects: The table below (Table 13) shows the specific rankings given to each of the three masks on the final day of the test in response to a questionnaire (Appendix C). This table clearly shows that the subjects prefer the experimental type masks over the standard. A full 67% of the subjects ranked the standard mask as the poorest. Unfortunately since one subject failed to rank experimental mask I (but ranked experimental mask II twice), one cannot determine which experimental mask (I or II) is the one liked least by the subjects. It may not make any difference, since it appears that the subjects could not clearly differentiate the two on any of the questions asked on both Pre- and Post-Chamber Questionnaires.

Conclusions (Arctic Chamber Testing) – The chamber testing of the face masks indicated that all three masks kept the wearer's face warmer than it would have been without any mask. The experimental masks offered significantly more temperature protection to the wearer's nose and to the skin below his eye both while he was walking and sitting than did the standard mask. The experimental masks were equally effective in keeping these two areas of the face warm.

In spite of the masks, the subjects' facial temperatures decreased while their activity levels were low (during sitting phases) and either increased or remained constant while they were walking. These temperature decreases for the nose and the eye were greatest when the standard mask was worn.

All three types of masks were compatible with standard arctic headgear, goggles, and glasses. However, goggles and glasses fogged and frosted in the cold regardless of the type of mask worn.

Summary

1a. Both experimental masks met the requirement thet the field of vision not be restricted to a greeter degree than does the standard mask currently in use.

1b. Furthermore, the visual field was slightly greater with experimental mask II than with experimental mask I.

2a. The experimental mask produced more ecoustic attenuation than did the standard mask.

2b. The standard mask resulted in poorer speech transmission than did the experimental mask.

2c. Both the experimental and standard masks reduced the protective attenuation provided by the SPH-4 helmet.

2d. The experimental mask resulted in poorer speech intelligibility when an electricelly aided communication system was used.

3a. Pre-chamber testing indicated that all three masks (standard, experimental I, and experimental II) were virtually equivalent performance-wise with respect to rifle-aiming, ease of eating, ease of blowing nose, and compatibility with CVC and infantry helmets.

3b. Pre-chamber testing indicated that there were *slight* advantages of the experimental masks over the standard mask with respect to general comfort, and ability to drink, spit, and smoke.

3c. Pre-chamber testing indicated that the experimental masks were clearly superior to the standard mask with respect to maximum ease and speed of donning the mask.

4a. Arctic chamber testing indicated that, against the wind and cold, experimental masks I and II offered better protection of the wearer's skin just below the eye and the nose than did the standard mask; tempereture decrements in these two areas were more severe when the subject wore the standard mask.

4b. All three masks were compatible with standard arctic headgear, goggles, and glasses; however, fogging of goggles and glasses occurred regardless of the type of mask worn. No one mask was considered superior to any other in terms of retardation of fogging and frosting. In addition, the subjects were unanimous in their opininn that the glasses should not be worn with any mask because of the rapid fogging problem.

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Figure 1. Front view of Army standard cold weather face mask.

Figure 2. Side view of Army standard cold weather face mask.

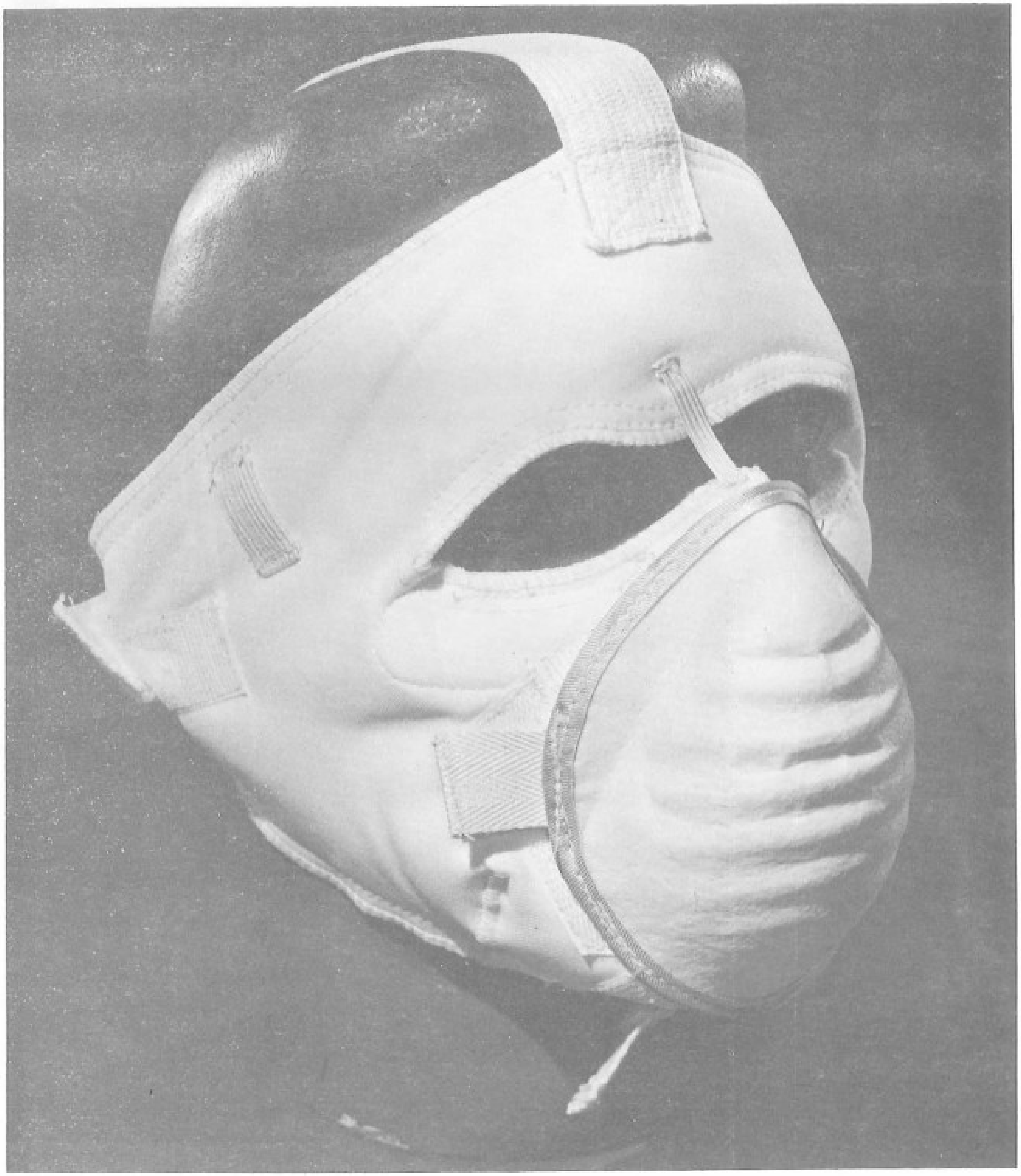

Figure 3. Front view of prototype cold weather face mask.

Figure 4. Front view of prototype cold weather face mask; oronosal barrier open.

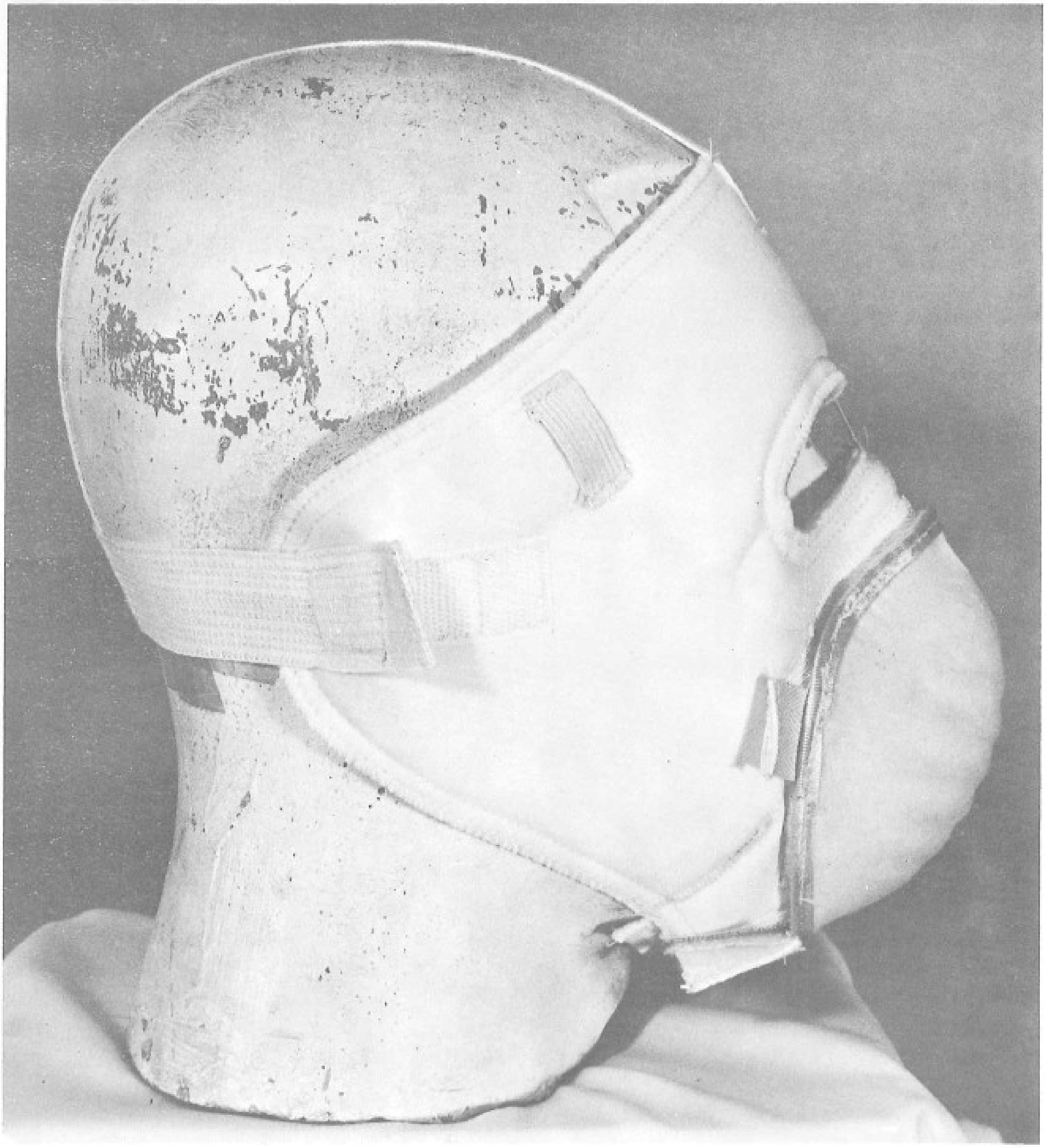

Figure 5. Side view of prototype cold weather face mask.

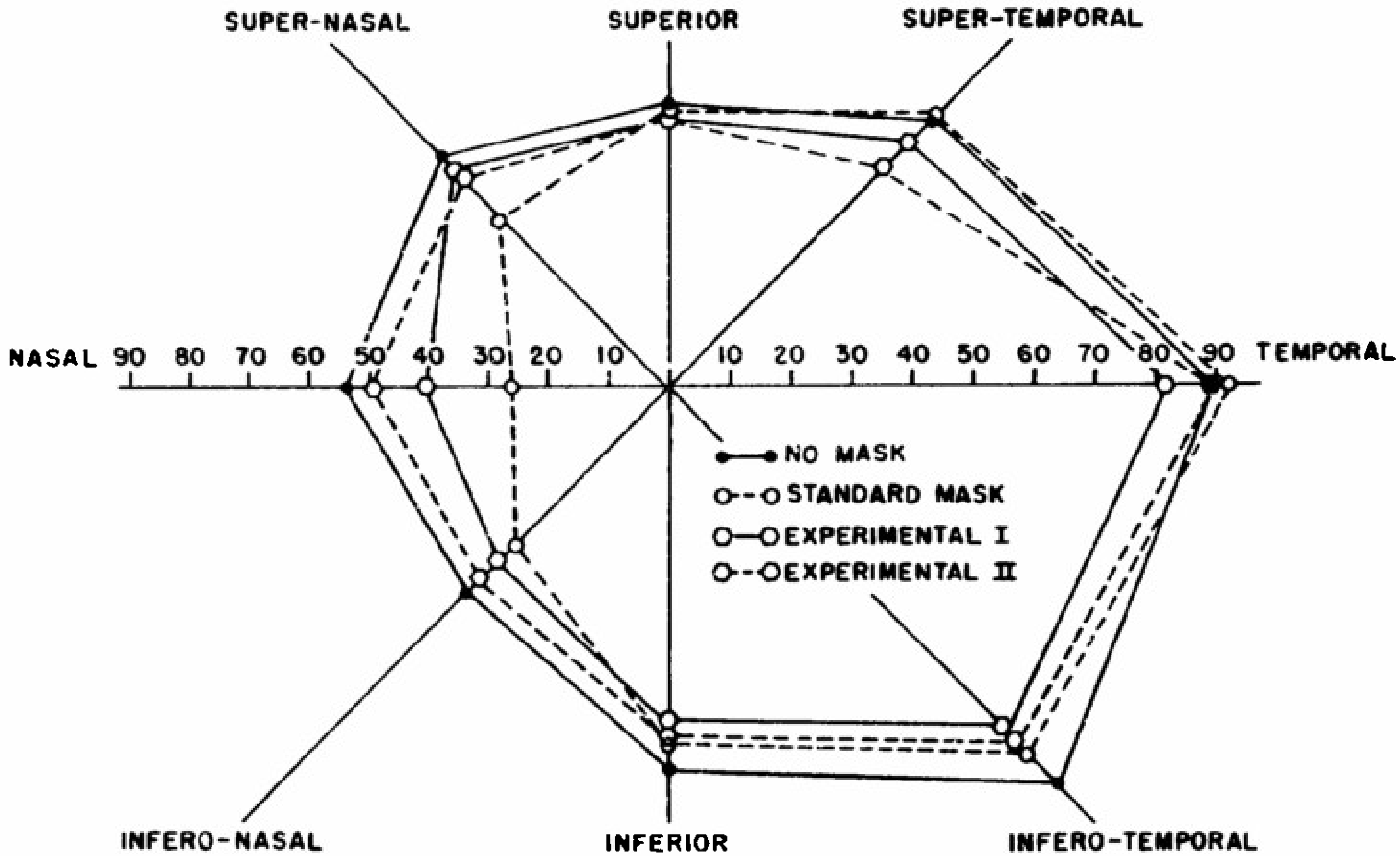

Figure 6. Mean Visual Field – Right Eye.

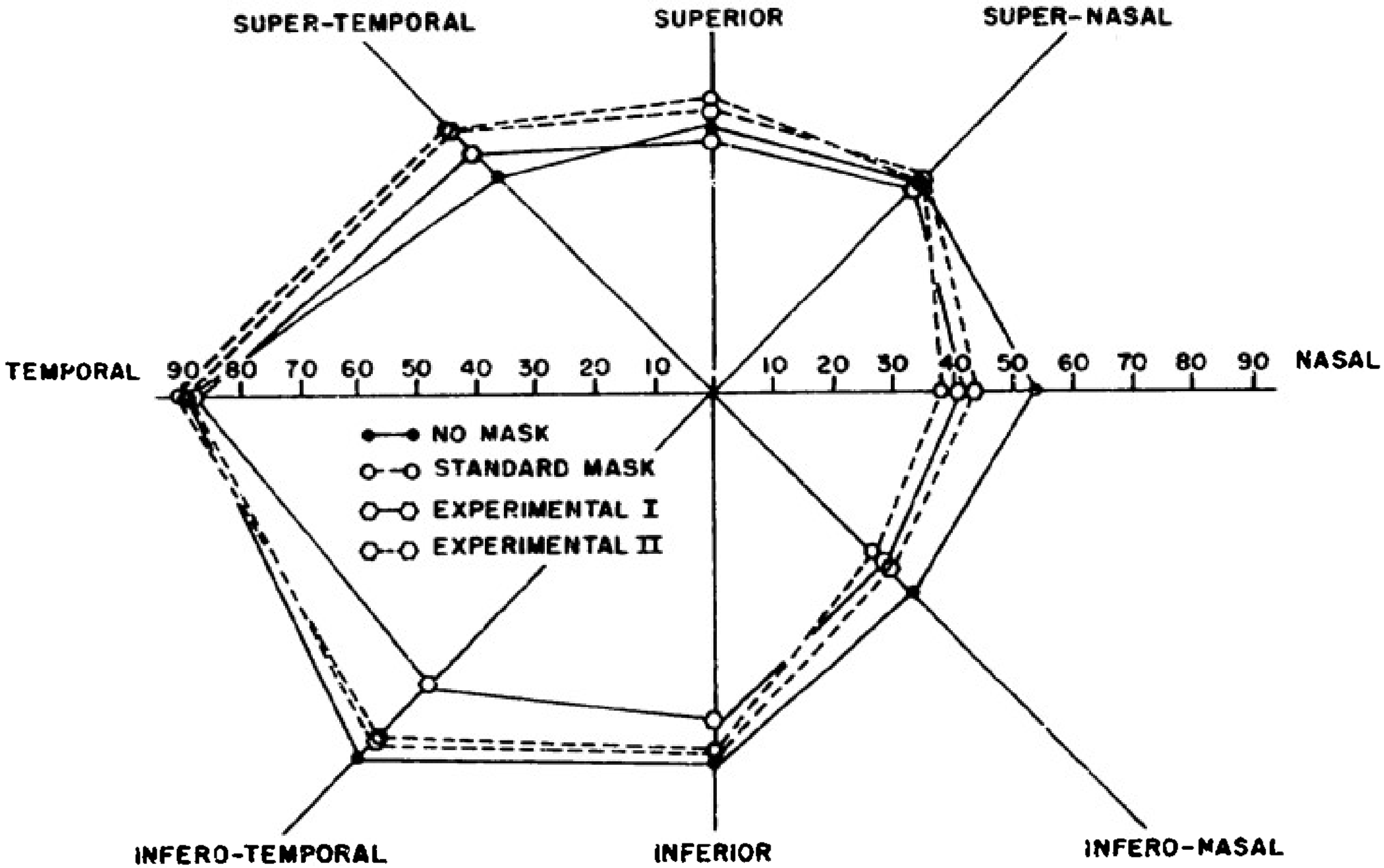

Figure 7. Mean Visual Field – Left Eye.

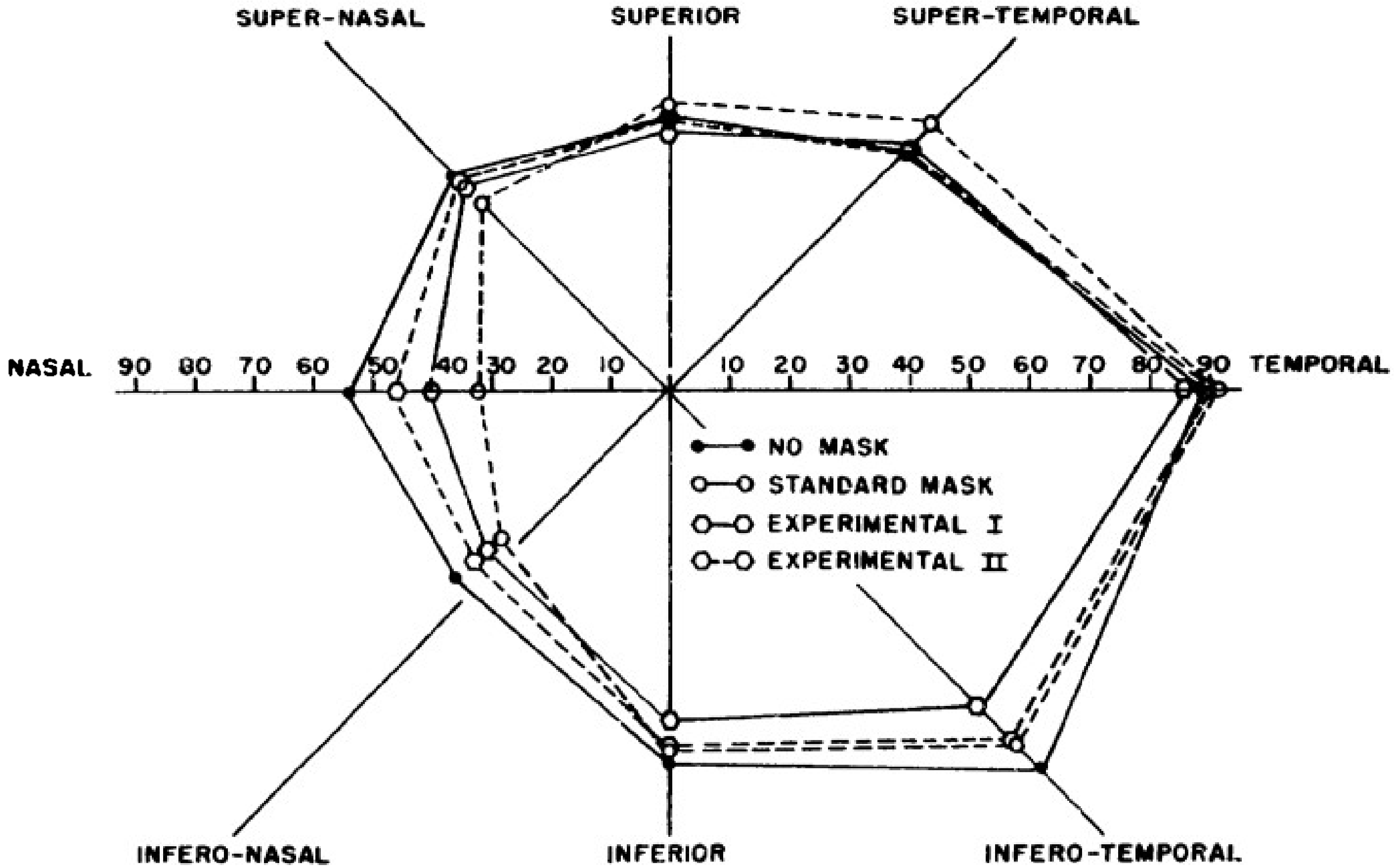

Figure 8. Mean Visual Field – Both Eyes.

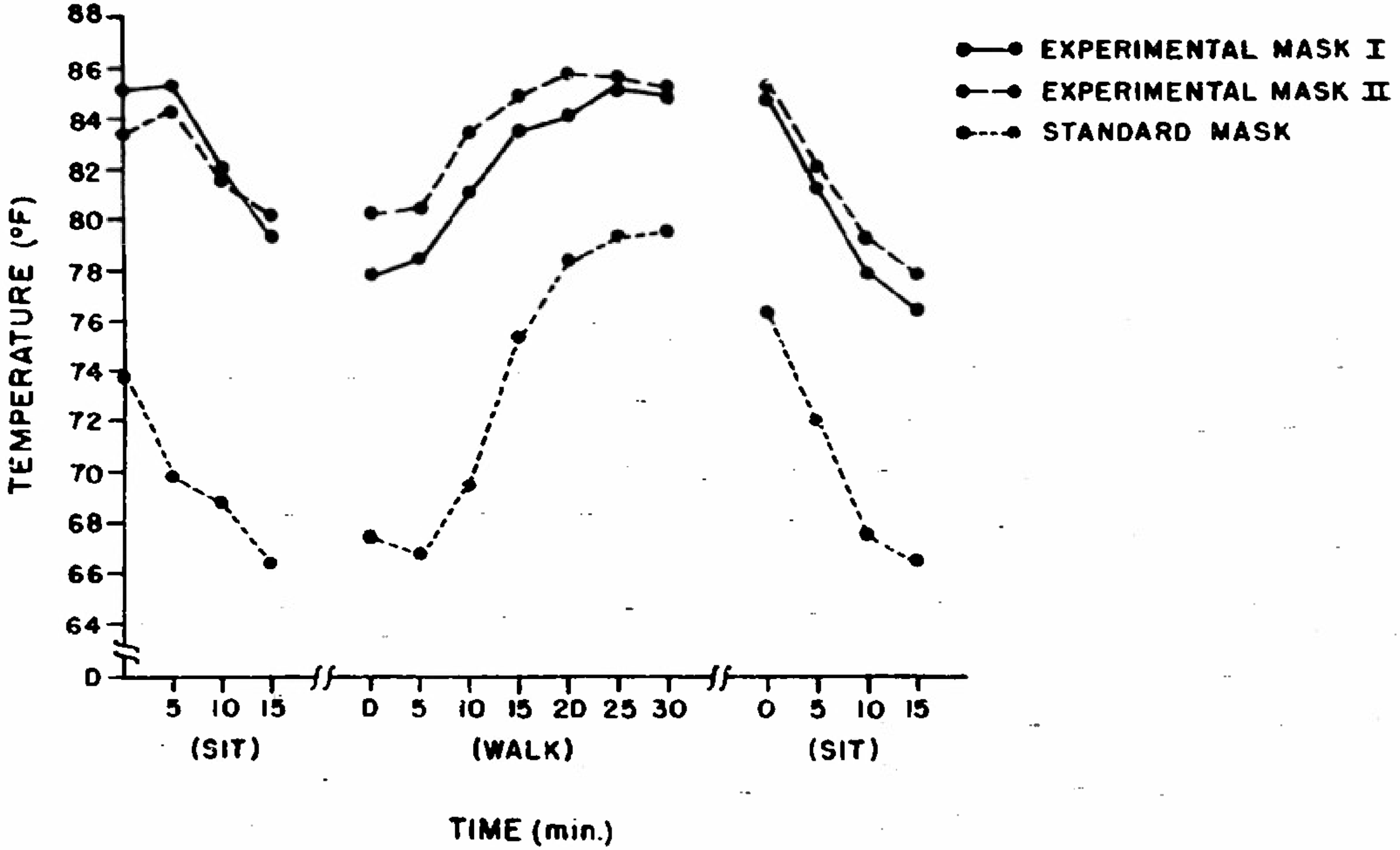

Figure 9. Mean temperature of the tip of the nose as a function of time, the type of mask worn, and the activity being performed.

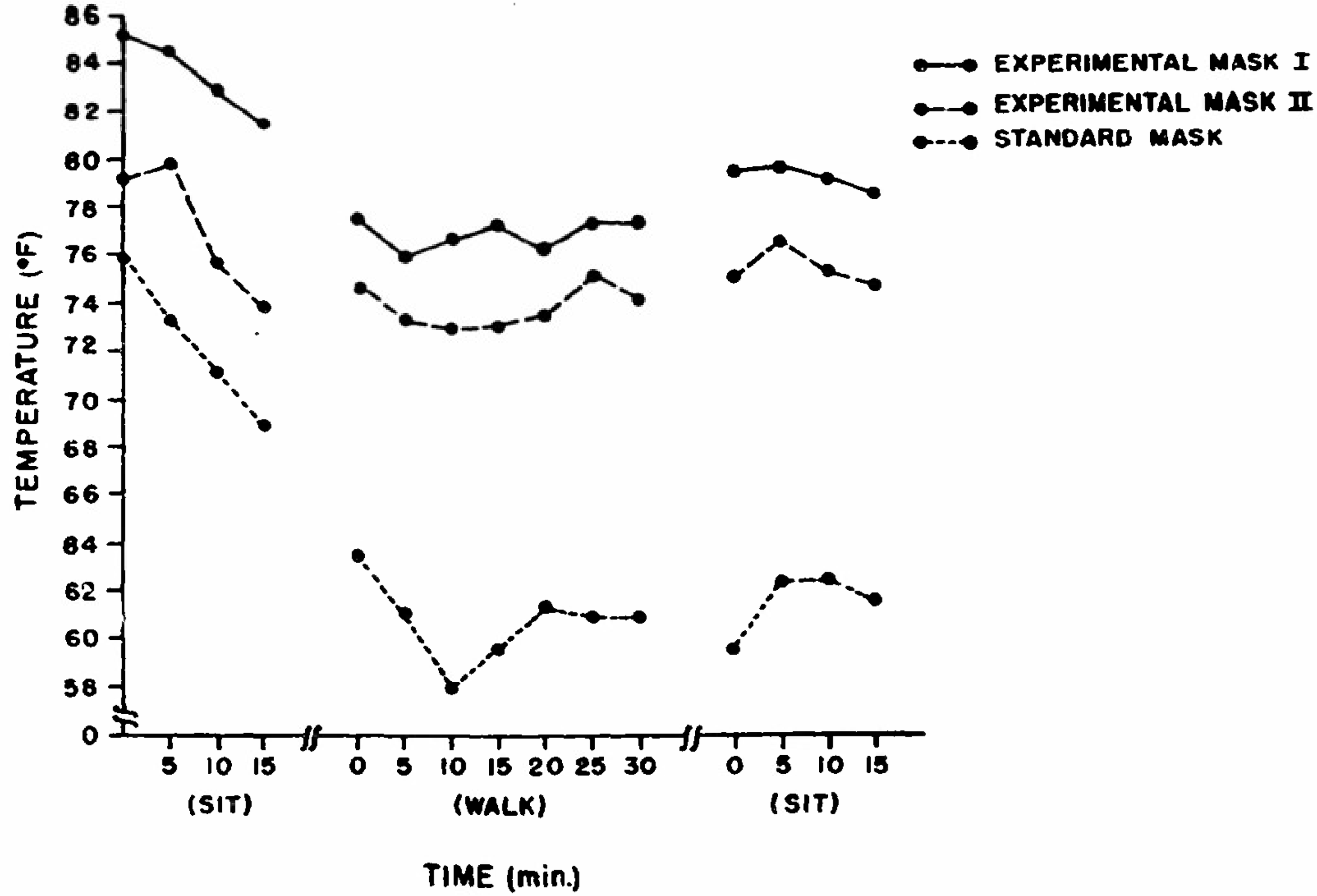

Figure 10. Mean temperature of the skin below the eye as a function of time, the type of mask worn, and the activity being performed.

TABLE I

Attenuation (in dB) of Face Masks Worn with Pile Cap and Parka Hood

Condition	125	250	500	Frequency (H_Z) 1K	2K	3K	4K	6K	8K
No Mask	0	0	0	5	6	11	18	18	19
Std Mask	1	3	3	2	7	12	20	20	22
Exp. Mask	1	4	3	3	10	16	21	22	28

*Each table entry represents the average of 12 runs; four subjects measured three times each.

TABLE 2

Speech Intelligibility with Face Masks, Pile Cap, and Parka Hood: Face-to-Face Communication

Condition	Intelligibility Score
Pile Cap, Hood, No Mask	*81% correct
Pile Cap, Hood, Std Mask	*73
Pile Cap, Hood, Exp Mask	83

* Difference between no mask and standard mask conditions just failed to show significance at 5% level.

TABLE 3

Attenuation (in dB) of Face Masks Worn with SPH-4 Helmet

Condition	125	250	500	1K	Frequency (Hz) 2K	3K	4K	6K	8K
No Mask	12	12	26	27	34	39	43	45	33
Std Mask	7	8	18	22	30	36	46	41	38
Exp Mask	3	4	14	20	17	28	32	29	24

*Each table entry represents average of 12 runs; four subjects measured three times each.

TABLE 4

Speech Intelligibility with Face Masks and Electrically-Aided Communication of the SPH-4 Helmet

Condition	Intelligibility Score
No Mask	*81% correct
Std Mask & SPH-4	81
Exp Mask & SPH-4	*63

Difference between no mask and experimental mask II conditions was significant ($p<.01$).

TABLE 5

Speech Intelligibility with Modified Experimental Mask

Talker Treatment	Listener Treatment: Mask	Listener Treatment: No Mask
Microphone Inside Barrier	*67.5% correct	82.2% correct
Microphone Outside Barrier	71.2	84.0
	69.4	83.1

*Effects attributable to listener treatment were significant (p<.01).

TABLE 6

Mean Performance Times on Rifle-Aiming Task

Subject	Mask		
	Standard	Experimental I	Experimental II
1	4.13	4.85	4.00
2	3.47	2.26	3.83
3	3.70	3.70	3.29
4	3.60	3.57	3.50
5	5.08	2.62	2.61
6	4.44	3.04	3.56
7	3.83	3.61	3.76
8	2.85	3.41	2.59
9	5.13	3.67	3.18
$\bar{x}$	4.02	3.41	3.36

TABLE 7

Results of Analysis of Variance of Rifle-Aiming Data

SV	df	SS	MS	F-ratio	p
Ss	8	3.98	0.49	1.13	N.S.
Masks	2	2.42	1.21	2.81	N.S.
Ss x Masks	16	6.97	0.43		
Total	13.37				

TABLE 8

Mean Performance Times on Donning Task

		Time to Don Mask
Subject	1	129.58 sec
	2	66.15
	3	70.63
	4	52.19
	5	76.08
	6	63.18
	7	95.58
	8	77.59
	9	82.11
Mittens		116.75
Wool Inserts		41.71
Standard Mask		117.86
Experimental I		61.87
Experimental II		57.97

TABLE 9

Results of Analysis of Variance of Donning Data

SV	df	*F*-ratio	p
Masks	2	54.07	< .01
Gloves	1	203.40	< .01
Ss	8	8.14	< .01
Masks x *Ss*	16	1.25	N.S.
Masks x Gloves	2	22.04	< .01
Gloves x Ss	8	1.09	N.S.
Masks x Gloves x Ss	16	2.22	

TABLE 10a

Rasults of Analysis of Variance of Nose Temperature Data

(Sitting Phases)

SV	df	SS	MS	F ratio	p
Eye Cover (C)	2	1276.016	638.008	0.474	
Ss/C	6	8072.104	1345.350	--	
Mask (M)	2	6372.822	3186.411	7.525	< .01
M x C	4	421.054	105.263	0.248	
Ss x M/C	12	5080.896	423.408	--	
Phase (P)	1	75.852	75.852	0.427	
P x C	2	13.822	6.911	0.038	
Ss x P/C	6	1064.993	177.498	--	
P x M	2	121.113	60.556	1.549	
P x M x C	4	77.817	19.454	0.497	
Ss x P x M/C	12	469.091	39.090	--	
Time (T)	3	1560.319	520.106	13.669	< .001
T x C	6	135.355	22.559	0.592	
Ss x T/C	18	684.868	38.048	--	

TABLE 10b

Results of Analysis of Variance of Nose Temperature Data

(Treadmill Phase)

SV	df	SS	MS	F-ratio	p
Eye Cover (C)	2	2463.225	1231.612	1.401	
Ss/C	6	5271.984	878.664	--	
Mask (M)	2	3608.423	1804.211	10.905	< .005
M x C	4	155.228	38.807	0.234	
Ss x M/C	12	1985.373	165.447	--	
Time (T)	6	2142.537	357.089	24.608	< .001
T x C	12	104.534	8.711	0.600	
Ss x T/C	36	522.405	14.511	--	
T x M	12	394.003	32.833	4.724	< .001
T x M x C	24	315.735	13.155	1.894	< .025
Ss x T x M/C	72	500.072	6.945	--	

TABLE 11a

Results of Analysis of Variance of Eye Temperature Data

(Sitting Phase)

SV	df	SS	MS	*F*-ratio	*p*
Eye Cover (C)	2	3669.064	1934.532	2.706	
Ss/C	6	4288.993	714.632	--	
Mask (M)	2	7721.349	3860.674	14.361	< .001
M x C	4	115.957	28.969	0.107	
Ss x M/C	12	3225.840	266.620	--	
Phase (P)	1	1771.026	1771.026	15.600	< .01
P x C	2	202.927	101.463	0.905	
Ss x P/C	6	672.536	112.089	--	
P x M	2	772.448	386.224	5.022	< .05
P x M x C	4	366.962	91.745	1.193	
Ss x P x M/C	12	922.799	76.699	--	
Time (T)	3	274.05[illegible]	91.353	7.698	< .005
T x C	6	35.250	5.875	0.495	
Ss x T/C	18	213.619	11.867	--	

TABLE 11b

Results of Analysis of Variance of Eye Temperature Data

(Treadmill Phase)

SV	df	SS	MS	F-ratio	p
Eye Cover (C)	2	8512.145	4256.072	4.001	
Ss/C	6	6381.825	1063.637	--	
Mask (M)	2	9145.470	4572.735	9.054	< .05
M x C	4	819.403	204.850	0.405	
Ss x M/C	12	6060.389	505.032	--	
Time (T)	6	123.534	20.589	1.876	
T x C	12	53.855	4.487	0.408	
Ss x T/C	36	395.084	10.974	--	
T x M	12	84.419	7.034	0.930	
T x M x C	24	224.430	9.351	1.236	
Ss x T x M/C	72	544.556	7.563	--	

TABLE 12

Arctic Chamber Observations (-50°F, 10 mi/hr wind)

Experimental Mask I	Experimental Mask II	Standard Mask
1. eye cover fog:	1. eye cover fog:	1. eye cover fog:
a) In general fog begins within first 5 min. of cold exposure.	a) In general fog begins within first 5 min. of cold exposure.	a) In general fog begins within first 5 min.
b) Fog completely covers eyewear within 15 min.	b) Fog completely covers eyewear within 15 min.	b) Fog completely covers eyewear within 15 min.
c) When eyewear precooled, total fogging retarded for another 15 min.	c) When eyewear precooled, total fogging retarded for another 15 min.	c) When eyewear precooled, total fogging not retarded.
2. oronasal frost:	2. oronasal frost:	2. oronasal frost:
a) Frost within first 10 min. of cold exposure.	a) Frost within first 10 min. of cold exposure.	a) Frost formed within 10-15 min. of cold exposure.
b) Breathing unhampered.	b) Breathing unhampered.	b) The frost formed in the "cavity" portions of the nose and mouth pieces where the skin was exposed.
c) Easily brushed off with arctic mitten (oronasal portion rarely removed by Ss).	c) Easily brushed off with arctic mitten (oronosal portion rarely removed by Ss).	c) Mouth, nose, and chin area of the mask were wet after the test. Rest of mask was relatively dry.
d) Oronasal portion and chin area of mask always wet after the test. Rest of mask dry to slightly damp.	d) Oronasal portion and chin area of mask always wet after the test. Rest of mask dry to slightly damp.	

TABLE 13

Mean Rankings of Masks

Mask	Rank			Total*
	1	2	3	
Standard	1	2	6	9
Exp. I	3	3	2	8
Exp. II	5	4	1	10

*Since one S failed to rank experimental mask I (but ranked experimental mask II twice), the totals are not each 9, as they should be.

Appendix A

Questionnaire: Pre-Chamber Testing

Name: Date:

Mask:

Check the type of eye protection worn:

(a) ________ None
(b) ________ Sun glasses
(c) ________ Prescription glasses
(d) ________ Goggles

1a. How clear were the instructions telling you how to put on and take off the mask?

________ Clear ________ Unclear

If they were not clear, why not?

1b. I found the fit of the mask to be

(a) ____ Very comfortable
(b) ____ Comfortable
(c) ____ Neither comfortable nor uncomfortable
(d) ____ Uncomfortable
(e) ____ Very uncomfortable

2. While you were wearing the arctic mittens, did you have any difficulty putting on the mask?

(a)________ Much difficulty
(b)__________Some difficulty
(c)__________No difficulty
(d)__________It was easy

3. While you were wearing the arctic mittens, did you have any difficulty taking off the mask?

(a)__________Much difficulty
(b)__________Some difficulty
(c)__________No difficulty
(d)__________It was easy

4. While you were wearing the wool insert gloves, did you have any difficulty putting on the mask?

(a)__________Much difficulty
(b)__________Some difficulty
(c)__________No difficulty
(d)__________It was easy

5. While you were wearing the wool insert gloves, did you have any difficulty taking off the mask?

(a)__________Much difficulty
(b)__________Some difficulty
(c)__________No difficulty
(d)__________It was easy

6. Did the mask interfere in any way with your wearing the pile cap and the arctic hood?

_________Yes _______________No

If so, describe.

Pile cap:

Arctic hood:

7. Did the mask interfere in any way with your being able to sight with the rifle?

(a)_________Interfered a great deal

(b)_________Interfered a little

(c)_________Did not interfere

Specifically, what were the problems involved?

8. Did the mask interfere in any way with

(a) Your being able to take water from the glass?

____________Yes ______________No

If so, describe.

(b) Your being able to spit out the water?

__________ Yes _______________ No

If so, describe.

(c) Did the mask get wet while you were drinking the water?

__________ Yes _______________ No

9. Did the mask interfere in any way with your being able to smoke?

(a) __________ Interfered a great deal
(b) __________ Interfered a little
(c) __________ Did not interfere
(d) __________ Did not smoke

Specifically, what were the problems involved?

10. Do you think you could eat if you had to while wearing the mask?

__________ Yes _______________ No

If not, why not?

11. Do you think you could blow your nose if you had to while wearing the mask?

Yes No

If not why not?

12. Did you actually try to blow your nose while wearing the mask today?

____________Yes ____________No

If so, what happened?

13. Do you think the mask can be worn comfortably with the helmets you wore today?

Yes No

Explain your answer.

Appendix B

Questionnaire: Post-Chamber Testing

Neme: Date:

Mask:

Check the type of eye protection worn:

(a)_________None

(b)_________Sun glasses

(c)_________Prescription glasses

(d)_________Goggles

PLEASE ANSWER THE FOLLOWING QUESTIONS AS THEY RELATE TO THE TIME YOU WERE IN THE ARCTIC CHAMBER ONLY.

1. As a screen against the wind, the mask was

(a)_________Excellent

(b)_________Good

(c)_________Averege

(d)_________Fair

(e)_________Poor

2. My face was

(a)________ Very cold
(b)________ Cold
(c)________ Cool
(d)________ About the right temperature
(e)________ Warm
(f)________ Hot
(g)________ Very hot

3. If you answered that your face became cold, indicate when:

(a)________ Sitting, prior to treadmill
(b)________ While on the treadmill
(c)________ Sitting, after treadmill

Also, indicate what parts of your face became cold: ____________________

____

____

4. If you answered that your face became too warm, indicate when:

(a)________ Sitting, prior to treadmill
(b)________ While on the treadmill
(c)________ Sitting, after treadmill

5. Did frost form anywhere on the face mask?

________ Yes ________ No

If so, when:

(a)________ Sitting, prior to treadmill

(b)________ While on the treadmill

(c)________ Sitting, after treadmill

Also, where did the frost form? ____

____

6. During the time you wore the mask in the cold, did your face become wet?

____________Yes ____________No

If so, during which portion?

(a)________Sitting, prior to treadmill

(b)________While on the treadmill

(c)________Sitting, after treadmill

7. The mask felt

(a)________Very heavy

(b)________A little heavy

(c)________Not heavy

8. Did the stiffener under the eye holes bother you in any way?

(a)________Bothered me a lot

(b)________Bothered me a little

(c)________Did not bother me

IF YOU WORE GOGGLES OR GLASSES, ANSWER QUESTIONS 9, 10 AND 11.

9. Did your glasses/goggles fog?

(a) __________ Did not fog up at all
(b) __________ Some portions fogged up
(c) __________ All portions fogged up

10. If your glasses/goggles fogged, incidate when they began fogging.

(a) __________ Sitting, prior to treadmill
(b) __________ While on the treadmill
(c) __________ Sitting, after treadmill

11. Should the glasses/goggles you wore today be worn with the mask?

__________ Yes __________ No

Explain your answer.

12. Did you ever remove the oronasal portion of the mask while you were in the chamber?

If so, when?

(a) __________ Sitting, prior to treadmill
(b) __________ While on the treadmill
(c) __________ Sitting, after treadmill

Why did you remove it? ______________________________

____

____

13. If you had any difficulty breathing through the oronasal part of the mask, indicate when:

(a) __________ Sitting, prior to treadmill

(b) __________ While on the treadmill

(c) __________ Sitting, after treadmill

14. Did the oronasal part of the mask ever become wet?

________________ Yes ________________ No

If so, when?

(a) __________ Sitting, prior to treadmill

(b) __________ While on the treadmill

(c) __________ Sitting, after treadmill

15. Did the oronasal part of the mask ever freeze?

________________ Yes ________________ No

If so, when?

(a) __________ Sitting, prior to treadmill

(b) __________ While on the treadmill

(c) __________ Sitting, after treadmill

16. The amount of frost forming on the oronasal part of the face mask was:

(a) __________ None

(b) __________ A little

(c) __________ Some

(d) __________ A lot

17. How often was it necessary to shed the frost on the oronasal part of the face mask?

(e) __________ Very often (once every five minutes or less)

(b) __________ Often (once every 5 to 10 minutes)

(c) __________ Occasionally (once every 10 to 20 minutes)

(d) __________ Seldom (once or twice)

(e) __________ Never

18. The frost which formed on the oronasal part of the face mask:

(a) __________ Was difficult to shed and caused significant discomfort

(b) __________ Was difficult to shed but caused little or no discomfort

(c) __________ Was easy to shed but caused significant discomfort

(d) __________ Was easy to shed and caused little or no discomfort

(e) __________ No frost formed

19. Did the mask have any adverse effects on your face or skin (e.g., rash or bruise)?

______________ Yes ______________ No

If so, what happened:

20. What did you especially like about the mask?

21. What did you especially dislike about the mask?

22. In general, under these environmental conditions my face was:

(a)__________Very comfortable

(b)__________Comfortable

(c)__________Fairly comfortable

(d)__________Neither comfortable nor uncomfortable

(e)__________Somewhat uncomfortable

(f)__________Uncomfortable

(g)__________Very uncomfortable

Appendix C

Final Questionnaire: Last Day

Name: Date:

1. Now that you have worn all three masks, which would you rate the best?

   (a) __________ Green Mask
   (b) __________ White Mask (I)
   (c) __________ White Mask (II)

   Why?

2. Which would you rate the second best?

   (a) __________ Green Mask
   (b) __________ White Mask (I)
   (c) __________ White Mask (II)

   Why?

3. Which would you rate as the poorest?

   (a) __________ Green Mask
   (b) __________ White Mask (I)
   (c) __________ White Mask (II)

   Why?

Appendix D

Frequency Tabulation of Subjects' Answers to Pre-Chamber Questionnaire

Question 1a: How clear were the instructions telling you how to put on and take off the mask?______clear;______unclear.

All Ss in all mask conditions reported that the instructions were clear.

Question 1b: I found the fit of the mask to be:

Mask	Very Comfortable	Comfortable	Neither Comfortable nor Uncomfortable	Uncomfortable	Very Uncomfortable
Standard	1	4	2	2	0
Exp. I	1	5	3	0	0
Exp. II	0	8	1	0	0

Question 2: While you were wearing the arctic mittens, did you have any difficulty putting on the mask?

Mask	Much Difficulty	Some Difficulty	No Difficulty	It was Easy
Standard	7	2	0	0
Exp. I	6	3	0	0
Exp. II	5	4	0	0

Question 3: While you were wearing the arctic mittens, did you have any difficulty taking off the mask?

Mask	Much Difficulty	Some Difficulty	No Difficulty	It was Easy
Standard	7	2	0	0
Exp. I	1	2	4	2
Exp. II	0	4	4	1

Question 4: While you were wearing the wool insert gloves, did you have any difficulty putting on the mask?

Mask	Much Difficulty	Some Difficulty	No Difficulty	It was Easy
Standard	1	6	2	0
Exp. I	1	4	2	2
Exp. II	1	5	3	0

Question 5: While you were wearing the wool insert gloves, did you have any difficulty taking off the mask?

Mask	Much Difficulty	Some Difficulty	No Difficulty	It was Easy
Standard	0	1	6	2
Exp. I	0	1	3	5
Exp. II	0	0	8	1

Question 6: Did the mask interfere in any way with your wearing the pile cap and the arctic hood?

With one exception (a subject wearing Exp. mask I), all subjects judged there to be no interference.

Question 7: Did the mask interfere in any way with your being able to sight with the rifle?

Mask	Interfered a great deal	Interfered a little	Did not interfere
Standard	0	3	6
Exp. I	0	0	9
Exp. II	0	0	9

Question 8a: Did the mask interfere in any way with your being able to take water from a glass?

Mask	Yes	No
Standard	3	6
Exp. I	0	9
Exp. II	0	9

Question 8b: Did the mask interfere in any way with your being able to spit out the water?

Mask	Yes	No
Standard	4	5
Exp. I	1	8
Exp. II	1	8

Question 8c: Did the mask get wet while you were drinking the water?

Mask	Yes	No
Standard	2	7
Exp. I	0	9
Exp. II	0	9

Question 9: Did the mask interfere in any way with your being able to smoke?

Mask	Interfered a great deal	Interfered a little	Did not interfere	Did not smoke
Standard	0	1	1	7
Exp. I	0	1	2	6
Exp. II	0	1	3	5

Question 10: Do you think you could eat if you had to while wearing the mask?

Mask	Yes	No
Standard	6	3
Exp. I	7	2
Exp. II	8	1

Question 11: Do you think you could blow your nose if you had to while wearing the mask?

Mask	Yes	No
Standard	8	1
Exp. I	8	1
Exp. II	9	0

Question 12: Did you actually try to blow your nose while wearing the mask today?

Mask	Yes	No
Standard	0	9
Exp. I	3*	6
Exp. II	0	9

*Of the three subjects who tried, two could do it and one could not.

Question 13: Do you think the mask can be worn comfortably with the helmets you wore today?

Mask	Yes	No
Standard	9	0
Exp. I	9	0
Exp. II	9	0

Appendix E

Frequency Tabulation of Subjects' Answers to the Post-Chamber Questionnaire

Question 1: As a screen against the wind the mask was:

Mask	Excellent	Good	Average	Fair	Poor
Standard	2	2	3	1	1
Exp. I	2	5	2	0	0
Exp. II	1	5	2	1	0

Question 2: My face was:

Mask	Very Cold	Cold	Cool	About the right temperature	Warm	Hot	Very Hot
Standard	1	1	3*	4	1*	0	0
Exp. I	0	0	1	5	3	0	0
Exp. II	0	1	1	5	2	0	0

*One subject reported that his face was "cool" at one point and "warm" at another.

Question 3: If you answered that your face become cold, indicate when:

Mask	Sitting, prior to treadmill	While on the treadmill	Sitting, after treadmill	N/A
Standard	3 *	1	3 *	3
Exp. I	2	0	1	6
Exp. II	2	1	2	4

*One subject reported his face was cool during *both* sittings.

Question 4: If you answered that your face became too warm, indicate when:

Mask	Sitting, prior to treadmill	While on the treadmill	Sitting, after treadmill	N/A
Standard	0	2	1	6
Exp. I	0	2	0	7
Exp. II	0	1	0	8

Question 5: Did frost form anywhere on the face mask?

All subjects in all conditions said "yes".

Mask	Sitting, prior to treadmill	While on the treadmill	Sitting, after treadmill
Standard	6	0	4
Exp. I	6	3	3
Exp. II	6	3	3

*There are more than nine responses per row because some subjects checked more than one time interval.

Question 6: During the time you wore the mask in the cold, did your face become wet?

Mask	Yes	No
Standard	2	7
Exp. I	2	7
Exp. II	2	7

If so, during which portion?*

Mask	Sitting, prior to treadmill	While on the treadmill	Sitting, after treadmill
Standard	1	1	0
Exp. I	1	2	1
Exp. II	1	2	1

*The frequency of reports are greater for Exp. masks I and II than indicated in the first half of the question because some subjects checked more than one response category.

Question 7: The mask felt:

Mask	Very heavy	A little heavy	Not heavy
Standard	0	1	8
Exp. I	0	1	8
Exp. II	0	1	8

Question 8: Did the stiffener under the eye holes bother you in any way?

Mask	Bothered me a lot	Bothered me a little	Did not bother me	N/A
Standard	0	1	8	0
Exp. I	0	4	5	0
Exp. II	0	4	5	0

Question 9: Did your glasses/goggles fog?

Mask	Did not fog up at all	Some portions fogged up	All portions fogged up	N/A
Standard	0	1	5	3
Exp. I	0	1	5	3
Exp. II	0	3	3	3

Question 10: If your glasses/goggles fogged, indicate when they began fogging.

Mask	Sitting, prior to treadmill	While on the treadmill	Sitting, after treadmill	N/A
Standard	4	3	1	3
Exp. I	5	2	0	3
Exp. II	5	2	1	3

There are more than nine responses per row because some subjects checked more than one time interval.

Question 11: Should the glasses/goggles you wore today be worn with the mask?

	Glasses		Goggles		
Mask	Yes	No	Yes	No	N/A
Standard	0	3	1	2	3
Exp. I	0	3	2	1	3
Exp. II	0	3	1	2	3

Question 12: Did you ever remove the oronasal portion of the mask while you were in the chamber?

Mask	Yes	No
Standard	1	8
Exp. I	0	9
Exp. II	2	7 *

*One tried but could not get it off.

If so, when?

Mask	Sitting, prior to treadmill	While on the treadmill	Sitting, after treadmill
Standard	1	0	0
Exp. I	0	0	0
Exp. II	0	2 *	1

*One tried but could not get it off.

Question 13: Did you have any difficulty breathing through the oronasal part of the mask?

Mask	Yes	No
Standard	2	7
Exp. I	2	7
Exp. II	1	8

If so when:

Mask	Sitting, prior to treadmill	While on the treadmill	Sitting, after treamdill
Standard	1 *	1 *	2 *
Exp. I	0	0	2
Exp. II	0	1	0

*One subject checked all three intervals.

Question 14: Did the oronasal part of the mask ever become wet?

Mask	Yes	No
Standard	3	6
Exp. I	3	6
Exp. II	4	5

If so, when?

Mask	Sitting, prior to treadmill	While on the treadmill	Sitting, after treadmill
Standard	1	2	0
Exp. I	2	1	0
Exp. II	2 *	2 *	2 *

*One subject checked all three time intervals.

Question 15: Did the oronasal part of the mask ever freeze?

Mask	Yes	No
Standard	5	4
Exp. I	8	1
Exp. II	2	7

If so, when?

Mask	Sitting, prior to treadmill	While on the treadmill	Sitting, after treadmill
Standard	1	1	3
Exp. I	4 *	4 *	3 *
Exp. II	2 *	1 *	1 *

*Subjects checked more than one time interval.

Question 16: The amount of frost forming on the oronasal part of the mask was:

Mask	None	A little	Some	A lot
Standard	1	2	2	4
Exp. I	0	1	8	0
Exp. II	0	1	7	1

Question 17: How often was it necessary to shed the frost on the oronasal part of the face mask?

Mask	Very often (one/≤ 5 min.)	Often (once/5-10 min.)	Occasionally (once/10-20 min.)	Seldom (once or twice)	Never
Standard	0	0	2	4	3
Exp. I	0	0	3	5	1
Exp. II	0	2	2	2	3

Question 18: The frost which formed on the oronosal part of the mask was:

Responses*

Mask	a	b	c	d	e
Standard	0	0	1	7	1
Exp. I	0	1	2	6	0
Exp. II	0	1	1	7	0

* a: Was difficult to shed and caused significant discomfort.

b: Was difficult to shed but caused little or no discomfort.

c: Was easy to shed but caused significant discomfort.

d: Was easy to shed and caused little or no discomfort.

e: No frost formed.

Question 19: Did the mask have any adverse effects on your face or skin (e.g. rash or bruise)?

Mask	Yes	No
Standard	1 (itchy)	8
Exp. I	0	9
Exp. II	1 (chin hurt)	8

Question 20: What did you especially *like* about the mask?

Mask	Responses
Standard	warm, easy to breathe, light
Exp. I	warm, good fit, breaks the wind
Exp. II	warm, good fit, light

Question 21: What did you especially *dislike* about the mask?

Mask	Response
Standard	cold nose, "everything"
Exp. I	cold eyes, "nothing"
Exp II	cold eyes, "nothing"

Question 22: In general, under these environmental conditions, my face was:

Mask	Very Comfortable	Comfortable	Fairly Comfortable	Neither Comfortable nor Uncomfortable	Somewhat Uncomfortable	Uncomfortable	Very Uncomfortable
Standard	0	3	4	0	1	1	0
Exp. I	1	3	3	0	2	0	0
Exp. II	1	3	4	1	0	0	0